



**HAL**  
open science

# Inverted optical reflection microscopy to study visibility and local charge modulation in electrolyte-gated monolayer MoS<sub>2</sub> Nathan Ullberg

Nathan Ullberg, Quentin Cogoni, Stéphane Campidelli, Arianna Filoramo,  
Vincent Derycke

## ► To cite this version:

Nathan Ullberg, Quentin Cogoni, Stéphane Campidelli, Arianna Filoramo, Vincent Derycke. Inverted optical reflection microscopy to study visibility and local charge modulation in electrolyte-gated monolayer MoS<sub>2</sub> Nathan Ullberg. Graphene 2021 - The 11th edition of European Conference and Exhibition in Graphene and 2D Materials, Oct 2021, Grenoble, France. . cea-03412872

**HAL Id: cea-03412872**

**<https://cea.hal.science/cea-03412872>**

Submitted on 3 Nov 2021

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Inverted optical reflection microscopy to study visibility and local charge modulation in electrolyte-gated monolayer MoS<sub>2</sub>

**Nathan Ullberg**

Quentin Cogoni, Stéphane Campidelli, Arianna Filoramo, Vincent Derycke  
Université Paris-Saclay, CEA, CNRS, NIMBE, LICSEN, 91191, Gif-sur-Yvette, France  
[nathan.ullberg@cea.fr](mailto:nathan.ullberg@cea.fr)

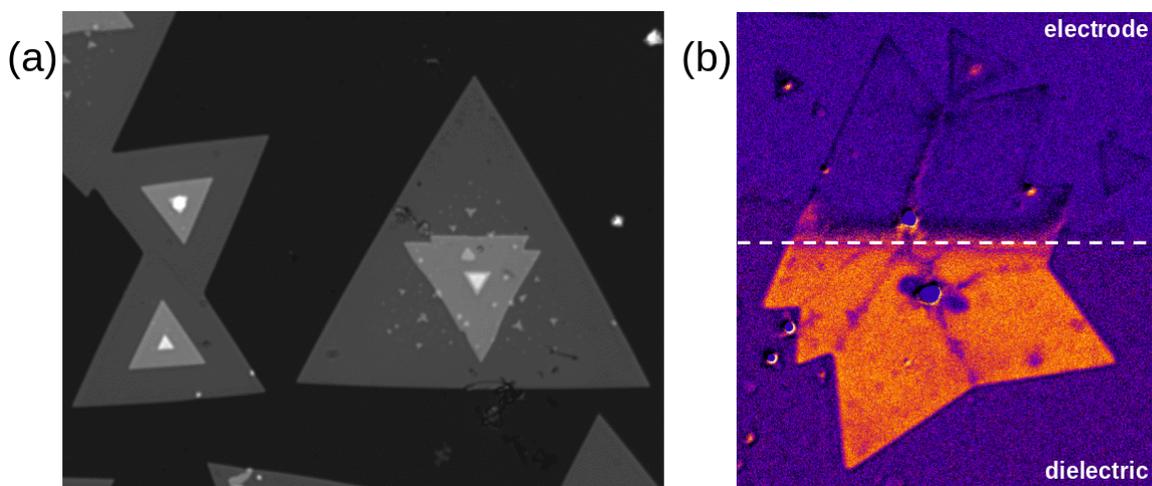
Inverted optical reflection microscopy is a powerful tool to study nanomaterials undergoing *in situ* processes. Its configuration is highly compatible to work with solvents, and the use of metallic anti-reflection coatings can enhance sensitivity to changes in optical path length (OPL), in addition to serving as an electrode. We recently demonstrated some of its assets for the high-contrast observation of graphene oxide and its chemical modifications [1] as well as for the *in situ* study of ultrathin molecular film growth [1,2]. The present work is focused on the study of CVD-synthesized MoS<sub>2</sub> monolayers, with two main objectives. The first is to enhance its visibility and OPL sensitivity to bilayers, grain boundaries and other topographic features, by use of suitable metallic and dielectric interference coatings combined with optimal incident wavelengths and illumination conditions. An example is shown in Figure 1a.

The second purpose is for real-time local charge imaging during electrolyte gating. The method is based on exploiting the high sensitivity of optical parameters ( $n, \kappa$ ) in 1L MoS<sub>2</sub> to its charge density, at certain wavelengths [3,4]. We show that optical images in charge accumulation and depletion states differ appreciably in optimized conditions, and allow for the direct extraction of charge profiles as shown in Figure 1b. A variation of this method, requiring additional FFT post-processing, was demonstrated in 2019 by Zhu et al. [5]. Additionally, we show that by using tailored multi-layer interference coatings, the optical sensitivity to gating is further enhanced. This work opens the door to measuring high-throughput *in operando* device physics parameters of nanomaterial electronic systems, using readily accessible optical equipment.

## References

- [1] S. Campidelli et al., *Sci. Adv.*, **3** (2017) e1601724
- [2] K. Jaouen et al., *Nanoscale*, **11** (2019) 6129–6135
- [3] Y. Yu et al., *Nano Lett.*, **17** (2017) 3613–3618
- [4] V. G. Kravets et al., *NPJ 2D Mater. Appl.*, **3** (2019) 36
- [5] H. Zhu et al., *ACS Nano*, **13** (2019) 2298–2306

## Figures



**Figure 1:** (a) Optical image of MoS<sub>2</sub> on a tailored multi-layer anti-reflection substrate, and (b) charge profile colorplot acquired by subtraction of accumulation and depletion images in electrolyte-gating configuration.